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MINE DESIGN AT HATTORF MINE AND LONGWALL MINING OF POTASH IN FRANCE AND SPAIN

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by

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SUMMARY

A brief visit to some potash mining operations in Europe provided insights on hangingwall strata behaviour, design parameters, water detection and control. Tabular deposits of potash are mined by room and pillar or longwall mining. Overall rates of recovery are in all cases higher than those obtained in Saskatchewan, e.g., 55-85% against 38-50%. Longwall mining is the preferred method at greater depth, for thin seams, and for seams with variations in height and dip. Output is about 250 to 500 tonnes/manshift per longwall. Larger extraction ratios in Europe are encouraged because orebodies are of more limited size and have thick layers of salt rock in the hangingwall. Mining is generally carried out at lower depths compared to Saskatchewan.

The Federal Institute for Geosciences and Natural Resources, Hannover, West-Germany, in connection with Gesellschaft für Strahlenforschung, GDF, (Agency for Radiation Research), Munich are very active in modelling salt behaviour to predict behaviour of a future nuclear waste repository in salt rock.

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CONCEPTION DES INSTALLATIONS D'EXTRACTION MINIÈRE DE HATTORF ET EXTRACTION DE LA POTASSE PAR LA MÉTHODE D'EXPLOITATION PAR LONGUES TAILLES EN FRANCE ET EN ESPAGNE

par

G. Herget*

RÉSUMÉ

La brève visite d'une installation d'extraction minière en Europe nous a donné un aperçu du comportement des couches de roches situées au-dessus de la surface de discontinuité, des paramètres de conception de l'installation et des méthodes de détection et de maîtrise du débit d'eau. Les dépôts tabulaires de potasse sont extraits par les méthodes de chambre et pillier, ou d'exploitation par longues tailles. Le taux global de récupération est dans tous les cas supérieur au taux de récupération atteint à l'installation d'extraction minière en Saskatchewan, e.g., de 55 à 85 % comparativement à des taux de 38 à 50 % pour cette dernière. La méthode d'exploitation par longues tailles est celle qui convient le mieux pour l'extraction en profondeur des gisements peu considérables et des gisements qui varient en hauteur et en profondeur. La production est d'environ 250 à 500 tonnes de potasse par période de travail personne/grand front. En Europe, on s'efforce d'obtenir des taux de récupération plus élevés parce que les amas de minerais sont de dimensions moindres et que des couches épaisses de sel gemme recouvrent les lèvres supérieures de la faille.

L'Institut fédéral des géosciences et des ressources naturelles de Hanovre en Allemagne de l'Ouest conjointement avec la Gesellschaft fur Strahlenforschung GDF, (Organisme de recherche sur la radiation) de Munich effectuent des recherches intensives sur le comportement du sel à l'aide du modelage dans le but d'obtenir des données sur le comportement de résidus nucléaires devant être éventuellement entreposés dans du sel gemme.

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INTRODUCTION

A need to increase extraction ratios in Canadian potash deposits has prompted a Federal Government initiative to assist the mining industry with funds to carry out research into improved mine design. To widen the experience base, and to see how European mine operators achieve higher extraction ratios, a brief visit was carried out to the Federal Institute for Geosciences and Natural Resources, Hannover; Asse-Research Mine, Wolfenbüttel, Germany; Room & Pillar mine of Kali & Salz at Hattorf, Germany; Longwall potash mining operation, Mulhouse, France and longwall mining operation of Potasas de Navarra, S.A., near Pamplona, Spain. Below some significant observations are described and references to detailed descriptions of the mine properties are given.

April 2-4, 1984, Federal Institute for Geosciences and Natural Resources (BGR)

This institute is very active in salt behaviour research (in situ monitoring of pillars, stress determinations by overcoring and flatjack compensation methods, numerical modelling).

Dr. A. Pahl, and Dr. Langer are in charge of the salt research group and are interested in cooperative research with Canada under the Canada/Federal Republic of Germany cooperative research agreement (1,2).

Dr. Pahl, initiated overcoring in salt rock of a device similar to the USBM meter, and finds that ground stress calculations are useful if these are interpreted with due consideration to the plastic/elastic behaviour of salt material (3). They have employed a hydrofrac unit in salt strata and are standardizing borehole tools to 86 mm diameter (dilatometer, Gloetzel cells, hydrofrac unit). At present a Stitz dilatometer with 200 m of hose costs about $30,000. For setting of Gloetzel cells (small flatjacks) in salt to monitor stresses, they find prestressing with resin better than waiting until convergence provides contact to instrumentation. Prestressing with magnesite cement has also been very successful.

Dr. Liedtke (4,5,6) has carried out work on numerical modelling and determined the probability of failure of a salt pillar. He is working on the strength of recompacted salt waste and has observed that compaction of salt waste by its own weight is larger than that from strata convergence. Thus,

backfill will not provide support to the roof but provide confinement to pillars. In compression, recompacted salt has 28% pore space but with addition of 2% water and consolidation the pore space can be reduced to 10%. Original salt rock has 1% pore space. The following densities were observed:

placed fill	1300 kg/m^3
compacted fill	1800 kg/m^3
original salt	2100 kg/m^3

Dr. Liedtke has analyzed the field data for a mine pillar in salt (20 m x 45 m x 15 m) with aid of program ADINA, obtained from K.J. Bathe, 1978. He found good agreement with field observations.

Dr. Wallner (7) has 15 years of finite element numerical modelling experience (worked with Prof. Wittke in Karlsruhe) and applied numerical model ANSALT (FEM, developed with CDC in Germany) to data on deformation and stress distributions obtained by Dr. F.W. Uhlenbecker at Hattorf potash mine and found good agreement. He also showed numerically, in another study for Denison Mines in Canada, how with time a ground arch develops in salt rock above two single openings. Kali & Salz AG with their share in the Denison Mine venture in New Brunswick had the mine layout provided by D. Mraz checked for stability.

Dr. Stefan Heusermann (3), calculates stress levels from strain recovery readings obtained by overcoring of salt rock. He analyses the data by using the unloading curve ($\Delta\sigma/\varepsilon$) of the overcored material and corrects for the plastic deformation occuring during overcoring when cutting past the sensors.

It appears that many unsolved questions remain in regard to the interpretation of overcoring tests in rock salt. At this point it is more advisable to obtain stress levels in salt by compensation measurements (flatjack or dilatometer) rather than by overcoring. German researchers indicated an interest to carry out cooperative work in Saskatchewan in connection in the MRL initiated field studies at COMINCO Potash or Central Canada Potash.

Mr. J. Thierbach, Geophysicist, (8,9) explained routine mapping of brine occurances and clay marker beds in salt rock with radar. Good contrast is obtained from brine because salt is non conductive and brine acts like a

metallic horizon. The portable system works up to 1000 m distance in clean salt but does not work in salt rock with clay beds because clay beds reflect radar impulses. Thus, radar is nearly useless for brine location in most of Saskatchewan salt rocks, except possibly the Esterhazy area. His experience indicates that most of the serious water problems in potash mines result from poor drilling technology or poor technique in sealing leaks, e.g., high pressure grouting rather than employing gentle pressures, cutting into vertical exploration drill holes during mining or drilling into water bearing beds with insufficient precaution. J. Thierbach has tried radar work at Central Canada Potash in 1972 (?). K & S (Kali and Salz AG, West Germany) have a patent on water detection in salt rock by radar probing and routinely carry out surveys in West German potash mines and in the Denison Mine orebody in New Brunswick. Three men can cover 1 km of drift in 8 hours and detect faults, marker horizons, and brine. If brine occurrences are located, their volume is estimated and a draining procedure is initiated. Radar has also been successfully applied in horizontal drill holes for distances up to 1000 m.

April 4, 1984 - Asse Research Mine, Wolfenbüttel

Mr. Rotfuchs of GDF (10), Gesellschaft für Strahlenforschung, München, explained the present program for salt strata research concerned with nuclear waste disposal in salt. Present studies determine change of total deformation and creep rate with elevated temperatures. Many of the investigations at Asse are supported by funds from the US nuclear waste isolation program. Analysis of data with a finite element program developed by GDF and the Battelle Memorial Institute has shown good agreement with field deformation measurements during salt rock heater tests (1983 Annual Report). The combined effect of heat and radioactivity on salt is determined at present with heater elements and cobalt 60 radio-active sources.

BGR is at present monitoring the deformation of a salt pillar at Asse, 1.5 m wide with H/W ratio of 2. A flatjack is mounted in the centre to control loading on a long term basis. This flatjack has a maximum expansion of 10 cm.

Operators at Asse mine have cut into consolidated salt backfill which had been in place for 60 years. It was so solid that the cutting machine operator noticed it only after he discovered pieces of brick and wood in the cuttings. The backfill was composed primarily of NaCl (95%) which possesses,

in its solid state, a uniaxial compressive strength of 80-120 bar. Testing of the consolidated backfill with a pore volume of 10-12% provided a tensile strength of 8 bar and a uniaxial compressive strength of 40 bar.

The Asse Research mine has some minor brine leaks, e.g., 1 L/min, but an adjoining mine had to close down because of water inflows. Tests on bentonite as a filler for salt backfill to improve water sealing properties were not successful. The brine (salt and water) destroys the sealing properties of the bentonite because of the break down of the clay structure. Sealing properties of waste salt are improved by adding anhydrite. References to engineering data on salt with emphasis on nuclear waste disposal are given under 11,12,13,14.

April 5, 1984 - Hattorf Mine, Philippsthal, Germany

Time was spent with Dr. Uhlenbecker, salt rock specialist and Mr. Gross who is in charge of undergound monitoring and testing.
Dr. F.W. Uhlenbecker (15,16,17) has 28 years of experience at the Hattorf mine and has obtained from field and laboratory investigations absolute convergence and deformation data for rooms and pillars. His data on stress distributions in pillars are unique and he has developed design guidelines for the deposit.

Difficulties in mining the deposit at Hattorf mine arise from violent CO_2 outbursts (up to 30 k tons of salt rock may eject) and if the potash seam becomes very thick. At present the properties of waste salt as backfill are being investigated and Uhlenbecker has evaluated the original design by D. Mraz for the Denison mine potash project in New Brunswick. He indicated that D. Mraz obtained with his mathematical approach (theory of plasticity) design data similar to the Uhlenbecker experience values.

Recovery of the Hattorf mine with their present room and pillar layout is about 65%. Present mining is done by drill and blast at a depth of 650-900 m. Field monitoring stations are placed every 200 m with 10 m long extensometers placed in the hanging wall of openings which are related to a datum (survey) point in the excavation. Originally a three point extensometer was used but, with experience, this was simplified to a one point extensometer to measure room convergence. 70% of the downward movement of immediate H/W strata is expected to occur on surface. Over a 20 year period surface subsidence has been 10-12 cm.

Short and long term tests performed in the laboratory are used to determine the strength of salt rock. In a short term test uniaxial compression is completed within one hour with a loading rate of about 1 MPa/min. In a long term test loads are applied at 1 MPa/min up to 50% of failure load and the sample is left under this load for 100 days. Various mineralogies in salt react differently. Sylvinite and Hartsalz do not show large differences in short and long term loadings. New Brunswick sylvinite does not break in a long term test but flows early whereas the Congo "sylvinite" fails at 20% of short term strength in a long term test.

At Hattorf mine, main drifts are stable at a depth of 800 m with a width of 16 to 18 m and a height of 2.5 to 4 m. Many intersection falls have occured. Older and abandoned drifts show roof fall potential. A comparison of Hattorf salt rock strata with Saskatchewan salt rock shows that Saskatchewan salt rock has a 10 fold higher convergence rate compared to Hattorf strata.

Testing of backfill in a consolidation unit, which accepts a 300 mm diameter x 150 mm high sample of ground NaCl, has produced from an original pore volume of 30 to 40% the following:

Axial pressure (MPa)	Duration (hr)	Strength (MPa)	Pore volume (%)
56.6	1	24.2	9.3
27.7	864	28.4	6.3

April 6, 1984 - Mr. H.O. Brune, Mining Engineer, Headquarters of Kali & Salz AG, Kassel

Information was obtained on Spanish potash properties and mine operations in West Germany (see references). Kali & Salz AG was formed by merger of Wintershall AG and Salzdetfurt AG in 1970 and then bought out Kalichemie in 1975. Kali & Salz AG thus controls all potash mining in West Germany. At their operations they have successfully drilled, with hydraulic jumbos, horizontal holes with 35 mm diameter at a rate of 700 m/shift and 41 mm holes at 200 m shift. In steep ore bodies sublevel open stoping allows high selectivity and production from small blasts to reduce the annoyance factor (blast vibrations) in densely populated areas. Sublevels are laid out with a vertical spacing of 20 m to limit hole deviation during drilling.

To reduce injuries and damage from loose rock in the roof, a roof scaling unit with a 3 m arm holding an impact hammer is used on a regular basis. Hydraulic roof scalers are available from Salzgitter (Germany) and Secoma (France).

April 9-10, 1984, Jean Breniaux, Chief Engineer, Technical Services, Mines de Potasse d'Alsace (MDPA) with headquarters in Mulhouse, France
Mr. Lourdel, Chief Engineer of Marie-Louise mine
Mr. Thebault, Mining Engineer

MDPA operate three mines (Theodore, Amelie, Marie-Louise) in the upper Rhine valley near Mulhouse. The potash seams are located 450 to 1100 m below surface. The seams vary between 1-5 m in thickness and are of post-Eocene age. At that time the Rhine graben was already established. The deposit dips steeply towards the north. Limits of mining are reached at a depth of 1200 m because of high rock temperatures (56°C). Rock temperatures reach 80°C at 1800 m below surface and plans are contemplated to mine the deeper part of the deposit by solution mining. The deposit is bedded with layers of marl, rock salt and potash. Strata are very regular.

The Marie-Louise mine has a shaft to 684 m. A few years back longwall mining appeared attractive to MDPA in regard to mining variable seam heights and variable dips, e.g., in Simon coal mine, East Lorraine a longwall in coal is operated with 63° dip and backfilling. Initial experiences with longwall mining of potash were very positive and four years ago (1980) MDPA made a complete transition from room and pillar mining to longwall mining in all of their potash mines (18,19,20,21,22). Caving occurs immediately behind the hydraulic supports (120 ton capacity). Occasionally a small void appears for a distance of up to 20 m. The strata break up into relatively small blocks. Often all the broken rock lies immediately against the vertical gob shields. Cover is generally more than 200 m of rock salt and no serious water problems have been encountered. Some inflow might occur when getting towards the edge of the deposit where the salt rock cover is thin or if by chance an old exploration drill hole is intersected by mining.

Cutting is done by double drum shearer (Anderson Strathclyde). Because of its weight, the unit is floor-mounted and moves on three rollers and skids. Level and height of cut can be controlled hydraulically. The shearer is pulled by chain and produces in one pass a cut of 1.17 m. On the return

cutters are changed and chocks are moved ahead. The face rarely gives trouble by spalling. At the head and tailgate special hydraulic supports are set for roof control and a special cut is made by blasting to set the shearer for the next cut. Thin layers of anhydrite and marl are used as reference lines and it is preferred to cut the floor in potash or salt and not in marl.

The ouput from a typical potash longwall is 1500 to 3000 t/day (21.75 hrs = one working day). The production shaft (1974) at Marie-Louise hoists from 11 longwalls 28,000 tons of ore per day in three shifts. The Mulhouse operations produce 55,000 tons per day.

The experience value for caving and fracture development above the mined horizon for a seam height of more than 2 m is 20 m. At a height of 1.2 m, flexure of beds has been observed only. A lower (1-5 m) and upper seam (1-2 m) are mined with the upper seam being mined first. In one area the lower seam had been mined earlier and when upper seam mining approached the old mining face only some deflection and delamination with bed separation was observed. A hand could be put between the strata, but no fracturation or caving was visible when mining the upper seam 25 m above the old seam.

The longwalls are operated in the retreat mode because the twin galleries (4 m each) providing access are stable. The pillar in between is 3 m. Face progress is about 500 m per year. Panels are generally 220 m wide and can be up to 5000 m long. At a depth of 600 m twin drifts are developed as head or tailgates along the whole length of the longwall panel and can be maintained (metal anchors and fully grouted resin bolts) for 10 years without significant roof maintenance. At a depth of 1000 m twin drifts are developed for shorter distances only because stand up time is less than one year. Observations have shown that twin drifts with a yield pillar in the middle are better than one drift only. No barrier pillars are left and recovery is close to 85%. Set up of a new face requires 2 to 3 months.

Nearly all the subsidence occurs within one year after mining at about 85-90% of mining height. On surface the outline of the 400 m radius shaft pillars can be seen clearly with a 3 m drop. On surface periodic level surveys are carried out. Wardell from Newcastle, England advised on a surface monitoring system and a predictive model is now available.

In the years 1955-1968 many convergence measurements were made underground. Now good experience values exist and very few measurements are made at present. Methane is a problem and accidents have occured in earlier years

due to asphyxiation or accidental burning. Rock bursts have occured in F/W strata but these are rare. Seismic monitoring has been tried but town and mining noises have been a problem. Some initial hydraulic fracturing in vertical drill holes has shown an anisotropic stress field with N-S-stresses larger than E-W stresses. MDPA have their own hydrofracturing unit with packer sizes of 76 mm. F.H. Cornet, U.S., does some of the consulting.

Experience in horizontal hole drilling is limited up to 500 m and they have found that an air flush system is inadequate. They have tried oil and brine but drilling of horizontal holes is considered an unrewarding experience.

The change over from room and pillar to longwall mining was relatively easy because the H/W behaviour was known from yield pillar mining. No testing or numerical modelling is carried out at present because the mature mine design is based on past experience.

At a temperature of 32°C only development work is allowed. Below this temperature the length of a production shift is prorated. Costs for a shearer with a cut of 1.1 m is about 4×10^6 FF, a typical conveyor = 2.5×10^6 FF, and one of the about 90 chocks in a longwall costs about 130,000 FF. The chocks have a support capacity of 120 tons each. If the longwall equipment requires modifications on site, due to a change of geological conditions (seam height, dip, etc.), the company has the shops to carry them out on site.

April 11-12, 1984, Potasas de Navarra, S.A., Beriain (Pamplona), Spain

Mr. Marie Jose Baselga, Mine Manager
Mr. Jose C. Camporro Bravo, Chief Engineer, New Development
Mr. Carlos del Olmo, Rock Mechanics Specialist

The mine operates in post-Eocene (Tertiary) strata and recovers a sylvinite bed of about 2-2.5 m. The sylvinite is overlain by 1 m of rock salt followed by a 15 m carnallite horizon. The rock salt layer is missing in places and carnallite in the back causes roof control problems. Carnallite is difficult to mine and is not being recovered. The carnallite is covered by an 80-90 m salt layer. Many faults with displacements of up to 600 m subdivide the ore in distinct sections. The more difficult and narrow seams of potash are mined by longwall mining with overburden generally 800 m. Room and pillar mining is carried out at shallow depth.

Personal access into the mine is by single-seater chairlift. Brine or water inflow is no problem in the deeper parts of the orebody. Methane is encountered at times.

The longwalls operate with a floor-mounted shearer (Anderson Strathclyde) and have 120 chocks for a 180 m long face. The hangingwall does not cave readily and every three passes the hangingwall is broken by drilling 6 m holes at 60° into the H/W and blasting. Difficulties of caving arise apparently from the strong marl layers embedded in the salt rock. Six longwalls are operated and recovery is about 80%. Access is by twin drifts and no barrier pillars are left. Each longwall produces about 300 t/hour requiring 5 men and a foreman. Observations in areas of shallow overburden have shown that subsidence fractures extend 200 m above the mining horizon. Subsidence is 90% of mining height (23,24,25,26,27,28).

A new small southern field is being developed by the room and pillar method with 66-70% recovery. In this field potash beds contain 35% K_2O due to a post depositional enrichment process. Overburden varies between 150-250 m and the salt cover is thin below a water bearing conglomerate beds. Pillars are designed according to tributary area theory based on short term strength tests (29,30). Stable excavations are aimed for, because subsidence would upset buildings in the village above. A safety factor of 2.0 has been chosen and the layout calls for 150 long rooms and pillars with a width of pillars of 3.5 m and chambers 12 m. Every 150 m a room is not excavated so a 19 m wide barrier pillar is obtained.

The design is being checked in present development by convergence and extensometer readings to a depth of 2.5 m. If strain in the first 1.5 m above the roof (bolted with resin anchors of 1.8 m) does not exceed 1 mm/m, the roof is considered stable. Far more deformation occurs if the roof is not bolted.

A computer model NONSAP, (H.J. Bathe, Wilson) is being set up to check the design based on short term strength data obtained under triaxial conditions from various sources (Dr. Potts, Newcastle-Upon-Tyne, England; National Engineering Institute, Lisbon, Portugal; and the Mining School of Madrid). Consultants have been there from England, France and Germany. Strength test results are very similar to data published by K.H. Hofer and P. Knoll (1971), East Germany. Creep tests have shown that critical deformations are 3-5% (salt), 6-11% (sylvinite), 2-5% (carnallite). (See also paper by Bradshaw and Lomenick: Rheology of salt in mine workings, Geology-Technology

Gulf Coast Salt, Sch. Geoscience, LSU, 1970, p 109-123). Two overcoring tests have been carried out for stress determinations in pillars with the USBM meter. Solution mining is being considered for mining remaining pockets of salt which do not justify development.

Rock salt is the preferred material for locating development drifts, conveyors, and access drifts. The long term stability of rock salt even justifies development below the mining horizon. At a depth of about 200 m below surface, drifts in rock salt have been standing for 20 years without deterioration. If carnallite appears in the roof, drifts or entries need to be re-worked every 2 years if bolts and mesh are installed. The break up in the roof occurs up to 60 cm above the roofline within a period of two years for openings 6 to 6.5 m wide and 3.6 m high.

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